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DEVELOPMENT OF INSTRUCTIONAL MATERIALS FOR A FUSED CHEMISTRY-PHYSICS COURSE. FINAL REPORT.

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THE PRESCHOOL INVENTORY BEGAN AS AN ANSWER TO THE NEED FOR SOME TYPE OF INSTRUMENT THAT WOULD PROVIDE AN INDICATION O OWMUCH A DISADVANTAGED CHILD, PRIOR TO HIS INTRODUCTION TO HEAD START, HAD ACHIEVED IN AREAS REGARDED AS NECESSARY FOUNDATIONS FOR SUBSEQUENT SUCCESS IN SCHOOL. MEASURING BASIC INTELLIGENCE WAS NOT THE GOAL. RATHER, THE INVENTORY WAS AN ATTEMPT TO DEMONSTRATE THE FACT THAT THE DISADVANTAGED CHILD WAS FUNCTIONING AT A DEFICIT AT THE TIME HE BEGAN SCHOOL. IT WAS ALSO TO BE USED ON A BEFORE-AFTER BASIS AND TO BE AVAILABLE AS AN INDEX OF EDUCATIONAL ACHIEVEMENT ASSOCIATED WITH HEAD START. THE AUTHOR CONCLUDES THAT THE INVENTORY SHOULD BE MORE SYSTEMATICALLY STANDARDIZED BEFORE BEING MADE AVAILABLE FOR PUBLICATION. (APPENDIXES INCLUDE THE INSTRUMENT AND AN ADMINISTRATION AND SCORING MANUAL.) (C.O.D.)

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Development of Instructional Materials For a Fused Chemistry-Physics Course

FINAL REPORT

6/16/67

SUBMITTED BY:

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WILMINGTON, DELAWARE

MAY, 1967

COOPERATIVE RESEARCH PROJECT NUMBER 6-8843

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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FINAL REPORT

DEVELOPMENT OF INSTRUCTIONAL MATERIALS FOR A FUSED CHEMISTRY-PHYSICS COURSE

Cooperative Research Project Number 6-8448

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BACKGROUND

College preparatory (secondary) students with interests in the Arts and Humanities need a broad understanding of physical science. In most high schools they select one year of chemistry, not physics and avoid the study of physics in college. A need existed for a fused chemistry-physics course for these students which would a) embody fundamental concepts from both physics and chemistry with no unnatural barriers between the discipline and b) expose the processes of science through experience.

OBJECTIVES

1. To develop selected instructional materials for a fused chemistry-physics course for secondary students.
2. To develop further the teaching methods and materials for this course (which has been taught for four years at Brandywine High School).
3. To evaluate critically two years of team teaching experience in this course.

PROCEDURES

The writing conference extended from June 20, 1966 to August 5, 1966. During these seven weeks the Principal Investigator and the two staff teachers met daily either in individual or group sessions. The consultants and the Project Directors joined the group periodically for one-half or full day discussions.

During the first two weeks the group worked closely with consultants and literature to establish the goals and objectives of the course. A new point of view, an emphasis on the process of science developed out of the investigations into the field of semantics. The last five weeks were spent on specific developmental assignments:

1. Analysis of characteristics, needs and future educational goals of high school students for whom this course is intended, academic students oriented towards arts and humanities.
2. Development of the logical process-relationship of the essential concepts leading up to one major understanding of the course - ENERGY.
3. Development of a course outline which organizes and integrates the concept content and related processes.
4. Preparation of a teachers' guide and student materials for units I, II, and III.

   I - Communication

   II - Invariant Relations

   III - Motion

During the period of September 1, 1966 to May, 1967 the course has been taught to 220 students by two staff members on the writing team, Mr. Howard and Mr. Cameron and a teacher new to the school. Mr. Miller supervised the teaching and the weekly planning sessions during the year. Pilot editions of the two additional units, IV and V were written.

IV - Forces

V - Energy

The teaching of the course was completed using three additional units VI - VIII which had been previously taught, but were not substantially rewritten to correspond to the new process-conceptual framework. The content of these three units is

VI - Electrical Nature of Matter

VII - Kinetic Molecular Theory

VIII - Electromagnetic Radiation

The final report was compiled during April, 1967.

Reports on the course were made to a) the entire science staff of the Alfred I. duPont School District, b) visitors from other districts and state department, c) the Delmarva section of the American Association of Physics Teachers, d) the National Convention of the National Science Teachers Association in Detroit, March 20, 1967.

The team approach to the teaching of this course was not expanded. Rather the team approach to the planning of a) classroom techniques, b) laboratory methods and, c) evaluation was emphasized. More concern developed this year with the process oriented teaching than the team teaching techniques per se.

RESULTS

1. A new innovative approach to the teaching of chemistry-physics to high school students has been developed based on deliberate exposure of the processes of science.

2. The Curriculum Guide for teachers and students has been prepared for the three initial units. This guide contains a teacher's point-of-view, student readings, student laboratories and written activities. Two additional units are in the pilot stage of development.

3. The course has had phenomenal success with 220 high school students whose college and career interests are oriented towards the arts and humanities.

4. The teaching staff and the administration have evidence that the new course produced higher student interest, participation and success as evidenced by attitude, grades, and requests for counseling. This course can be characterized by:

a. Very high motivation of the students. This is especially significant since these students are primarily interested in Arts and Humanities, not science and/or mathematics. It is our hypothesis that these students are motivated and interested because they recognize transfer of learning between the processes of science and their cultural subjects.

b. High level of learning. The incidence of failures and drop-outs was significantly lower than in previous years.

c. Acceptance and use on the part of students of mathematical models and scientific terms. Anecdotal records of teachers indicate that these students accept and use mathematics (equations, graphs, slope) and scientific terms readily if the technical terms are introduced by the inductive procedure developed in this course.

d. Noticeable increase in student participation in the learning activities. As the patterns for observations and interpretations are developed in the laboratories and classrooms the classes become more independent of the teacher. There is evidence of reapplication during the year of previously learned processes and content.

5. The staff has developed greater insight into learning theory, the process of science and the major concepts and laws describing the physical world.

6. The concern of educators that the enrollment in high school and college physics is drastically low, thus producing "liberally" educated citizens with no knowledge of physics can be met directly with this course. The liberal arts student in this course develops an appreciation of physical science and the processes of classifying and attaining knowledge which he finds applicable in other disciplines.

CONCLUSIONS

I. It is possible to construct a process centered curriculum which meets the following requirements.

A. Contains the essential content in a fused Chemistry-Physics course.

B. Develops a conceptual scheme of increasing degrees of abstraction.

C. Develops and/or employs a mathematical riger compatible to college preparatory course requirements.

D. Utilizes laboratory facilities and apparatus common to the needs of national curricula in chemistry and physics.

(A) The criteria for the selection of content is the ability of the topic to serve as a medium for developing a step or technique pertinent to the process. In as much as a wide variety of topics may be adaptable to this need, the content of the course can be made very similar to any physical science course. In relation to item D above, a particular school would select those topics for which it had facilities and apparatus. Some innovations are required such as in the unit of motion where many and varied examples of motion are called for. In these cases common lab equipment can be utilized with a little ingenuity.

(B) The very essence of the process of science leads to the discovery of concepts. It is the organization of this course which directs this discovery (inductive) process towards the summit which in this course, is the concept of conservation of energy.

(C) Elements of algebra, plane geometry, and trigonometry are employed in the course. Graphs and slopes are extensively used. In every

case the mathematics is first used as an analytical tool and later as a model of behavior or a means of communicating a relationship. Because the tool (mathematics) simplifies a problem of analysis or communication it presents no burden to the student, and is of secondary importance to the main problem.

II. The direct approach to the inclusion of the process in a science curriculum increases a student awareness of and skill in using the elements involved in the process.

Unfortunately the above statement cannot be validated on a quantitative basis. Anecedotal reports from the teachers using this curriculum indicate that

1. Students apply a previously used technique to new problems.
2. Laboratory exercises are performed with great care. Lab reports are organized to show the analysis which provoked the conclusion.
3. Mathematics is not avoided, but is utilized to its fullest extent.
4. Students understand and appreciate the development of a big picture - that science is more than isolated items.

III. The barriers which deter understanding and appreciation of science can be overcome at the senior high school level.

The attitudes toward science and mathematics which are prevalent among so many students often are due to an apprehension of the mathematical rigor and the language of mathematics and science. It is possible to develop a degree of skill in a technique of the process and hence learn content within the framework of lay language. Introducing new terminology to a previously learned technique does not stigmatize the technique. In a like manner mathematics becomes an advantageous tool and not an insurmountable barrier.

IV. Given the motivating factors of inspiring and critical consultants, adequate time and compensation, and sympathetic leadership, it is feasible for practicing teachers of science to develop an original science curriculum.

The many attempts by schools to revise a science curriculum have met with limited success. This was our experience in our initial effort to develop a fused Chemistry-Physics course. Our initial effort was influenced by (1) the teachers existing pattern of teaching, (2) existing published textual materials, and (3) limited periods of time. The result of the previous effort was a reshuffling of previous sequences of units which lacked a cohesive pattern.

The success of this present effort is due to (1) a long uninterrupted period of time (seven weeks) which was condusive to creative thinking, thorough investigation, critical discussions, and productive writing; (2) inspiring and tantilizing consultants; (3) adequate clerical assistance which made possible the dissemination of ideas among the group and the utilization of time for creative purposes, and (4) understanding and sympathetic leadership.

The above ingredients provided the fertile ground in which the education, experience, and dedication of the science teachers could be effectively channeled toward the creative thinking needed to develop a new curriculum.

The development of a new science curriculum involves the production of textual materials, laboratory guides, and associated materials. Very little published material is usable as it exists. Writing, critisizing, and revision are time consuming. Within the

time allotted less than one half years work was completed. Additional work was organized to a partial extent. Staff time during the school year is inadequate to prepare the additional materials.

V.. The professional growth of teachers as indicated by a change in habitual teaching patterns and a new view to the total educational process is rapid, of great depth because of the intimate responsibility toward curriculum design.

Among the teachers involved with this project (all having participated in graduate work beyond the masters level) it was the unanimous opinion that they learned more from this experience than in most of their graduate work.

VI. Being intimately concerned with curriculum design is condusive to promoting a change in the habitual teaching pattern of teachers.

The teachers involved in this work acquired a new outlook as to the meaning of science and an understanding of modern educational psychology. A precept of the educational theory which substantiates the emphasis placed on the direct teaching of process is that it is the major contribution of science to other fields. This same transfer of skills from one discipline to another is evident in the total change in teaching patterns among those teachers involved in this effort. The changes have effected curricular and extra curricular endeavors.

IMPLICATIONS

I. The evidence of success of this initial effort has been so striking that more and varied efforts should be made to validate the assumption that a process centered curriculum utilizing modern educational theory, as exemplified by Bruner and Vygotsky, and employing the basic principles of semantics has merits for science curriculum to all pupils.

As a first step the present curriculum should be completed and annotated for a wide distribution with the hope that other groups will find it helpful as a guide to curriculum revision and design incorporating the direct teaching of the process of science.

II. Schools and school systems should be encouraged to design or modify a curriculum for their particular needs. The direct approach to the teaching of the scientific process is not found in nationally developed science curriculum. With modification and additions this could be accomplished within the framework of existing curricula on a level to benefit any particular class.

Teacher involvement in curricular design is beneficial in upgrading the teaching process by increasing the teachers awareness of modern learning theory.

III. Evaluation of pupils progress in the learning of the process of science presents a difficulty due to the lack of valid tests and measurement devices. Teachers habitually test for content. If the testing and measuring devices do not follow the goals of the course then the measurement of the success of the course is dependent on subjective judgement.

Our best judgement at this time indicates a high degree of success in student understanding, using, and appreciating the process of science and the conceptual schemes incorporated in the course. This judgement should be substantiated by a valid testing program.

Furthermore inadequate testing which emphasizes rote learning of content could destroy the goals of the course by forcing the student to revert to old patterns of rote learning instead of developing patterns of critical thinking.

BIBLIOGRAPHY

A bibliography is included in the Curriculum Guide containing 41 references.

PUBLICATIONS

The publications to date include the Curriculum Guide and this final report.

A paper about this course was presented at the National Science Teachers Convention, Detroit, Michigan, March 19, 1967 by the Principal Investigator. A summary of the 15-minute talk was sent to NSTA office in Washington, D. C. for inclusion in their publications on the convention (in press).

APPENDIX

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May 4, 1967

Dr. Phyllis Magat
Project Director

Dear Dr. Magat:

One of the curricular highlights at Brandywine High School this year has been the success of the Unified Chemistry-Physics Program. The opportunity for teachers to develop curriculum during the summer months, made possible by a grant from the U. S. Office of Education, was a major factor in the improvement of this program.

The following observations are pertinent to the evaluation of this project:

1. Changes in teacher attitudes and approaches to the teaching of science are quite evident.

2. Teacher and student morale is high.

3. Student performance is improved over past years.

4. Discipline problems and student requests to drop the course are virtually non-existent. This has been a problem in the past.

Sincerely,

Glenn M. Sanner

Glenn M. Sanner
Principal

GMS:dp

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TO: Dr. Phyllis L. Magat
Project Director

The reaction of students electing the Chemistry-Physics I course since its origin has been basically favorable and since the new format has been introduced attitude and acceptance of the course offering has become complimentary and enthusiastic. During the past year there has been not one question or mild complaint registered in these offices on any aspect of the subject. This is refreshing and in itself a rather full endorsement of all the students now enrolled.

During the years of Chemistry-Physics I's existence as a course offering we have never had its status or acceptability questioned. In view of our placement of 84% of the graduating classes in over 400 institutions of post-secondary learning in 43 states and 3 foreign countries, this speaks for itself.

John F. Curran

John F. Curran
Chairman, Counseling Staff

JFC:h
5/4/67

CHEMISTRY - PHYSICS I

PROCESSES AND CONCEPTS

A CURRICULUM GUIDE

Alfred I. duPont School District
Concord Pike at Mt. Lebanon Road
Talleyville, Delaware
Wilmington, 19803

CHEMISTRY - PHYSICS I
PROCESSES AND CONCEPTS

A CURRICULUM GUIDE
1966

ALFRED I. DU PONT SCHOOL DISTRICT
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Talleyville, Delaware
(Wilmington, 19803)

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CURRICULUM GUIDE

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Objectives of the Chemistry-Physics Course

College preparatory (secondary) students whose primary interest is in the Arts and Humanities need a broad understanding in the physical sciences. In most high schools these students select one year of chemistry, not physics, and avoid the study of physics in college. A need exists for a fused Chemistry-Physics course for these students which would embody fundamental concepts from both physics and chemistry and which would place these concepts in a pedagogical framework which exemplifies the structure and process of science.

The goals listed below are valid for any science course but are especially critical for the college preparatory student who will have few, if any, subsequent courses in science.

1. Understand the elements involved in effective communication skills
2. Understand the process of placing objects and events in categories or classes
3. Understand the structure leading to a concept
4. Understand some fundamentals laws and theories of science
5. Understand the utility of a concept in predicting and controlling associated events.
6. Understand and appreciate the role of science in society
7. Understand that the processes of science are applicable to learning and rational critical thinking

THE STRUCTURE OF SCIENCE AS RELATED TO THE TEACHING OF SCIENCE

From a study of the literature in the fields of semantics, communication, and cognition it was hypothesized that the direct teaching of the structure of science was the most reasonable approach to attain the goals and objectives of the Chemistry-Physics course. The works of Hayakawa[17], Chase[8], Conant[11], and Vygotsky[40] provide a basis for the understanding of the processes of learning. Bruner[7] has summed up his own and Piaget's theories of learning in his book, The Process of Education. The contributions to the Fifty-Ninth Yearbook of the National Society for the Study of Education[18] are essentially in agreement with Bruner. The course of study is a product of our interpretation of the theories proposed by the above mentioned authors.

Bruner makes four major claims in support of the teaching of structure. The first of these claims is that the subject will be more comprehensible to the student when he becomes aware of the fundamental ideas or laws governing the behavior of matter and can fit his own observations and inferences into this framework.

Secondly, Bruner says that the student will remember more subject matter if this subject matter is built around a central theme of structure. In fact, he says that any detail not placed in a structured pattern will be rapidly forgotten. Bruner also points out that subject matter taught in this manner will be more interesting, and will, therefore be retained longer by the learner.

Thirdly, teaching the structure of science leads to a greater "transfer of training." In fact, Bruner points out that transfer will occur if the student understands the fundamental principle, or structure, of a subject.

Bruner's fourth point is that by emphasizing structure in elementary and secondary schools, the gap between "advanced" knowledge and "elementary" knowledge can be reduced.

Bruner believes that a student who grasps the general principles of structure of a subject and has an attitude of learning and inquiry toward the subject has mastered the subject.

The implementation of this course must revolve about discovery for one's self. This should lead the student to an attitude of inquiry, of hunching, of guessing, of using one's intuition, and, when the student has learned the structure of science, to predict by deductive reasoning the behavior of matter in related areas of science and the humanities.

In reaching these objectives, a sequence of topics and associated curricular material are selected to lead the student from the simple structure of science to higher levels of concepts which direct his attention to the structure and underlying principles.

In the beginning the student should see that things may be grouped by selecting one of several sorting factors and be shown how to select a sorting factor which will allow him to reach some objective.

The student is made aware of the invariant relation and seeks this invariant relation time and time again in analyzing his data collected by observing the behavior of matter.

The student is encouraged to build his own mental model of a concept from his observations and graphic analysis of the phenomena encompassing the concept in question. With the model in mind, he is encouraged to predict how matter will behave when subjected to stresses similiar to and different from those which helped formulate his model.

It is believed that in deliberately making the student aware of the process of teaching structure, the student will better understand the need for developing a good background of principles upon which to make predictions, draw inferences, and nourish his intuitive processes so that he becomes confident in his hunches and guesses in fields which he has not directly studied.

There is no experimental evidence that the teaching of structure is the best way to approach the teaching of science, in fact, Bruner calls for research in many areas of "structure teaching".

This course is an attempt to bridge the gap between theory and classroom practice.

A SURVEY OF THE CHARACTERISTICS OF C-P I STUDENTS INCLUDING

1. Ability
2. Mathematics background
3. Post high school activity.

Prior to 1962 a study found that many of the college-bound students were taking chemistry merely to fulfill the college entrance requirement of a laboratory science. A group of teachers then suggested that a course be designed for the college-bound student who was not particularly interested in the sciences on a collegiatelevel. This group submitted an outline to the guidance staff, who presented it to 40-50 universities, colleges, nursing schools and junior colleges. These institutions indicated that a course of this type (including elements of chemistry and physics) would fulfill the entrance requirements of a laboratory science. Chemistry-Physics I was started in September, 1962 and has continued to the present time.

On the following pages is an analysis of 338 graduates who had completed the unified chemistry-physics course.

Figure I shows the distribution of abilities as measured by the I. Q. scores. It should be noted that in Figure I according to the Otis I. Q. (Quick score 10th grade, error + or - 4 to 5 points) scores that the mean is displaced to the right 15 to 20 points. Therefore, while these students may not be interested in science, they are average or better in ability.

FIGURE I

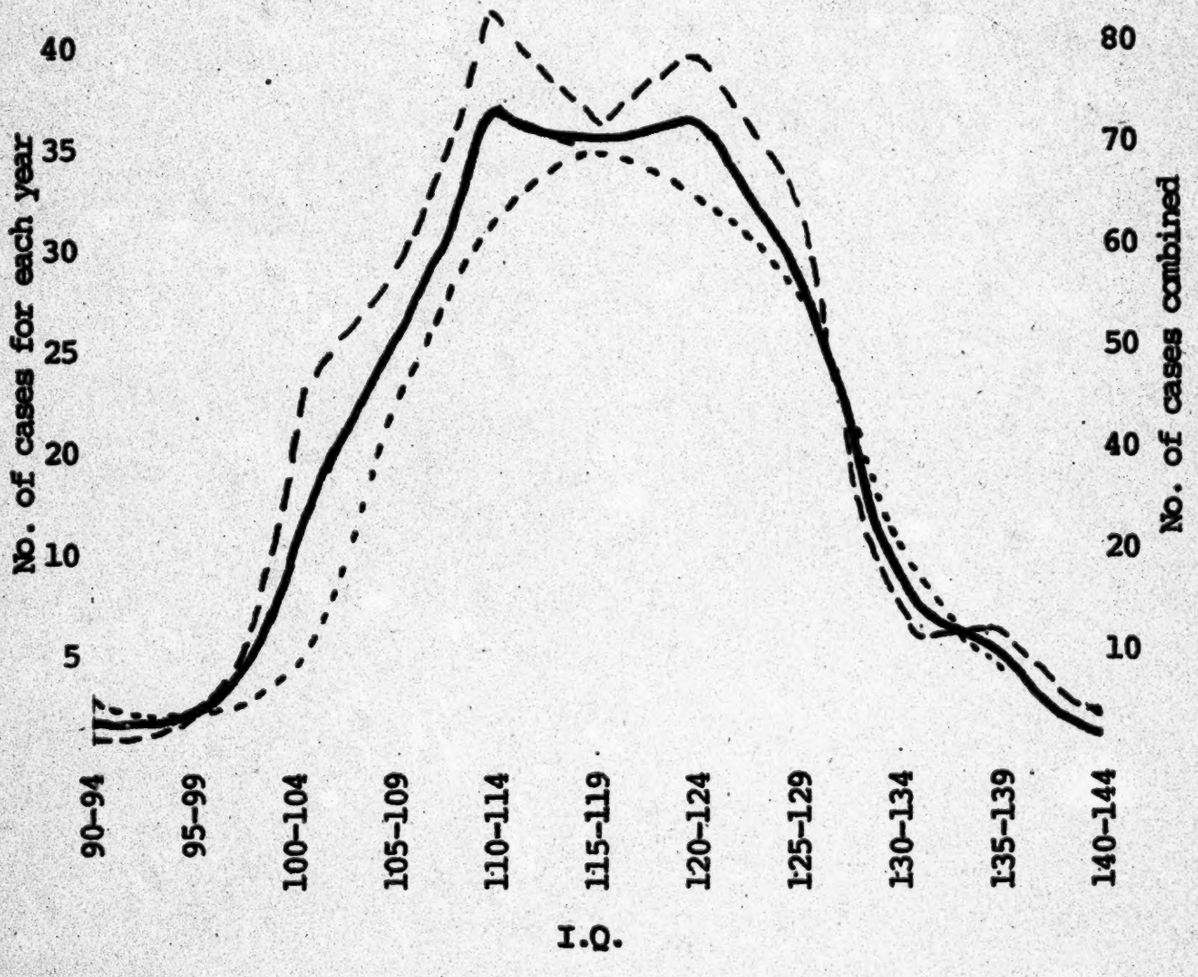
I. Q. SCORES OF C-P I STUDENTS

Otis I.Q. scores of 338 graduates (classes of '63, '64) who had taken C-P I.

KEY: I.Q. 1962-63 ——

I.Q. 1963-64 – – – –

I.Q. 1962-64 combined ——



Characteristics (cont.)

Table I shows the mathematics courses taken before and coincidentally with the chemistry-physics course, and indicates that the students had a common background in the area of algebra I and geometry up to the 1964-65 school year. The reorganization of the mathematics curriculum in the 1964-65 school year reduced the number of students who had an operational knowledge of geometry. Very few (13-15%) of the students have a knowledge of trigonometry.

Figure II indicates the areas former C-P I students are pursuing in post high school careers. These careers are described briefly here:

1. Four-year non-science includes majors in language, elementary and secondary education, music, liberal arts, art, sociology and other areas.

2. Four-year science includes mathematics, chemistry, biology, psychology and engineering along with related areas.

3. The two year technician includes laboratory technicians, drafting and related persuits.

4. The two year non-technical are those in business, secretarial and related areas.

5. Nursing includes both R. N. and degree candidates.

6, 7, 8, and 9 are self explanatory.

Ninety-ninety two per cent of the students taking C-P I pursued a post-high school education. Of all those who took C-P I, 65-75% entered a four year college or university while less than 10% pursued a science related education. From this data more than 90% of these students would fit the definition of "layman" relative to science.

TABLE I

MATHEMATICS BACKGROUND OF C-P I STUDENTS

Percentage of students who had been enrolled in the following mathematics courses.

School Year	No. Students	Mathematics Courses									
		* Alg. I	* Geo.	* Alg. II	# Adv. Alg.	* Adv. Alg.-Trig.	# Alg.-Geo. I	# Alg.-Geo. II	# Alg.-Geo. III	* Bus. Math	* Gen. Math
1962-63	151	100	80.9	82.8		2.8				5.9	1.0
1963-64	187	* 100	* 82.2	* 83.5	#	* 4.3	#	#	#	*	* 5.6
1964-65	150	* 98	* 97.4	* 71.2	# 1.3	* 13.3	# 2.0	# 2.9	# 1.3	*	*
1965-66	205	* 88.5	* 49.3	* 61.9	# 4.0	* 15.7	# 18.8	# 33.6	# 4.9	* 2.0	* 4.2

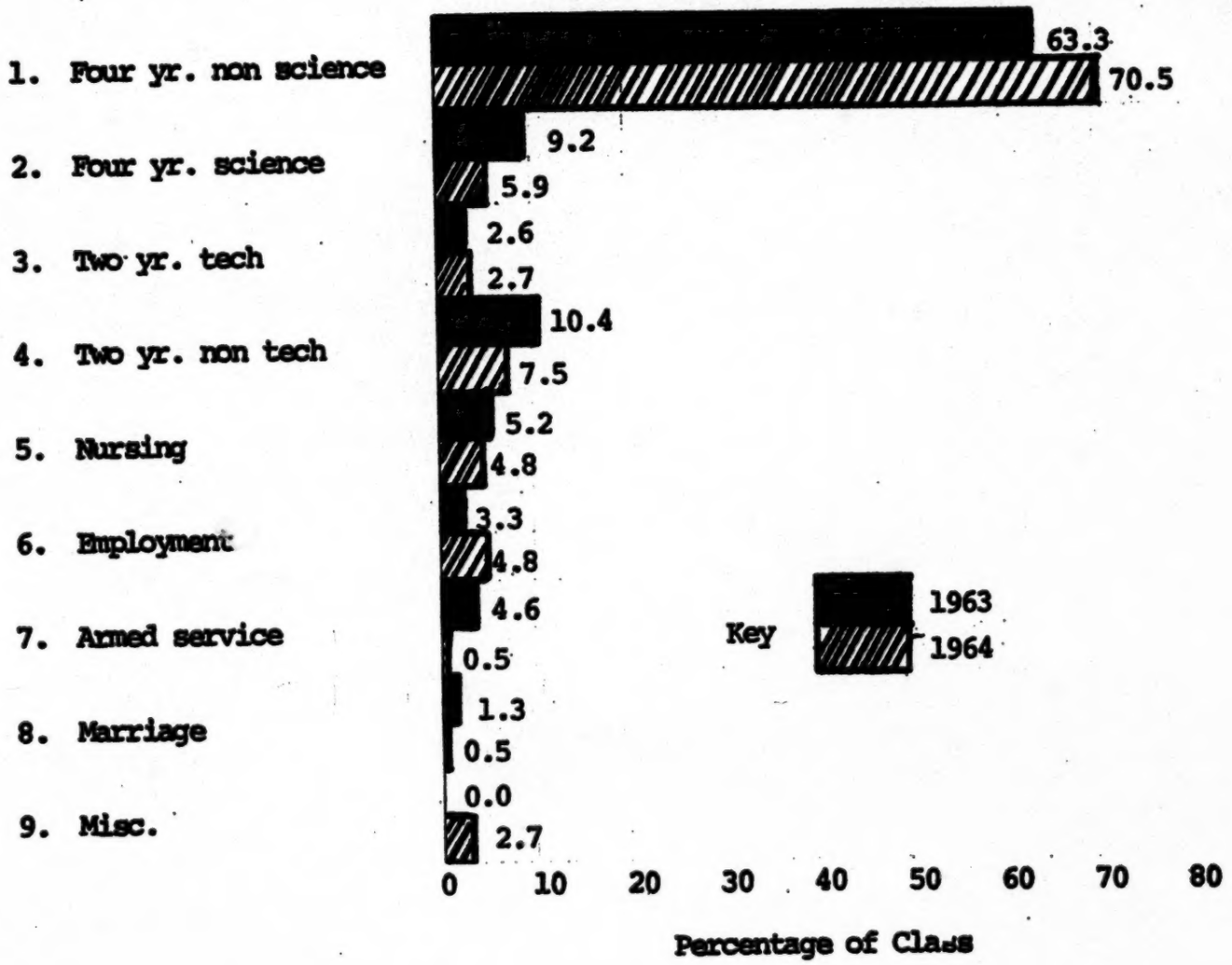
* These students included in Figures I and II.

Not offered in these years.

Alg-Geo I, Alg-Geo II, Alg-Geo III is a three year sequence which includes the content of the usual Algebra I and Geometry courses.

FIGURE II

POST HIGH SCHOOL ACTIVITY OF THE CLASSES OF 1963 AND 1964



The above information on the characteristics and careers of former C-P I students reinforces the original assumption that this course should have the full reign of a college preparatory course.

SCIENCE BACKGROUND OF C-P I STUDENTS[1]

The curriculum at the Junior High is in a state of change at the present time. The general science curriculum, as taught in the past few years, is being replaced by a full year of Life Science in the seventh grade, a full year of Earth Science in the eighth grade, and a full year of Physical Science in the ninth grade. This sequence is in effect this year in the seventh and eighth grades with the ESCp (Earth Science Curriculum Project) course being offered most students in the eighth grade. The ninth grade course at present consists of topics from physical science (physics and chemistry) and a very light treatment of some Life Science topics. IPS (Introductory Physical Science), a completely laboratory-oriented course, is being taught to several classes this year and will be expanded next year to all the average and better sections of ninth grade physical science.

All C-P I students will have taken BSCS (Biological Sciences Curriculum Study) biology in the tenth grade. This course is highly laboratory oriented meeting 260 minutes per week for 35 weeks.

The Junior High courses will become more laboratory oriented as laboratory facilities and more equipment become available. The typical ninth grade general science class now spends approximately ten per cent of its time in laboratory and 15 per cent of its time in class demonstrations. The working laboratory group usually consists of about five students working together with one set of apparatus. The remaining time is spent in teacher-student discussions, problem solving, and testing, with very little time devoted to "just plain lecturing."

Background (cont.)

Junior High students coming into biology have a good knowledge of elementary general chemistry including atomic structure, simple reactions and bonding. These students also have an elementary understanding of energy, mechanics, sound, heat, light, conservation of energy and the kinetic-molecular theory.

The areas where these students have little or no understanding are electricity, magnetism and radioactive decay.

In comparing the background of an incoming C-P I student, having successfully completed the above course offerings, to the seven "Conceptual Schemes of Science," proposed in the National Science Teachers' Theory Into Action[1] the following statements can be made.

1. Students have a knowledge of the fundamental particles and an understanding of the role the particles play as the "building blocks" of nature. The concept of the photon, however, is at best, rudimentary.

2. Students have a knowledge and understanding of several classification schemes both microscopic and macroscopic; both living and inanimate.

3. Students have a limited knowledge of the satistical approach to the behavior of matter. Particular areas that seem to need development are those involving very large numbers of very small particles acting randomly but, at the same time, with order, such as in electric current, radioactive decay and the thermodynamic description of the behavior of matter.

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[1] NSTA Theory Into Action, 1964.

4. Students have a limited knowledge of force and the interaction of particles through forces. An area of apparant need is more work on "force at a distance."

5. Students have a limited knowledge of concepts dealing with dynamic equilibrium for reasons outlined in number three above. Although the student is aware of the conservation of mass-energy, his model is of small dimensions (closed systems) and needs to be developed into universal all-encompassing model. His understanding of the energy distribution throughout equilibrium systems is extremely limited.

6. Students have been introduced to the terms "temperature", "heat" and the "kinetic-molecular theory" but they have a limited concept of the motions, momenta and energies of the particles of matter which lead to such manifestations as pressure, heat, temperature, electric current and electromagnetic radiation.

7. Students have studied interactions of earth systems, but have a limited understanding of the potential and kinetic energies involved in the various geologic and planetary systems.

It must be remembered that the incoming Chemistry-Physics I class of eleventh graders represents a very wide spectrum of various intellectual and emotional maturities with a correspondingly wide spectrum of conceptual development.

As a result of the mobility and growth of our suburban population about 20 percent of the students enrolling in Chemistry-Physics I will have transferred into the district after their junior high program, and about ten per cent will have transferred in after the tenth grade.

The sources of data on the science background of C-P I students include district reports[2] and Curriculum Guides and interviews with other science teachers.

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[2] Science, Course of Study, Alfred I. duPont School District, June, 1963

Junior High School Science Workshop, Interim Report, Alfred I. Dupont School District, August, 1964

Junior High School Science Curriculum, Student Understandings, Alfred I. duPont School District, February, 1965

Living Science in a Physical World, Alfred I. duPont School District, August, 1965

SUGGESTIONS FOR INTRODUCING C-P I

"SETTING THE SCENE"

The purposes of this lesson are to arouse the students interest in science; to create awareness of observing phenomena to stimulate the imagination of the students; to create the proper attitude toward safety regulations.

A few well chosen, dramatic demonstrations can accomplish these purposes. The demonstrations need not - should not - have scientific explanations. A discussion of a descriptive nature would be helpful in establishing a rapport which would lead to increased pupil participation in class discussions.

Hubert Alyea's, Tested Demonstrations, from the Journal of Chemical Education is a good source for chemical demonstrations and, in the area of physics, demonstrations in light, electricity, wave mechanics, and radioactivity would be useful.

In this preliminary lesson the teacher should be careful of the terminology he uses in describing the experiments to the students. The use of such terms as "see", "hear", "feel", "observe", should be used instead of "perceive" or "perception" since the use of the latter words will be developed in unit one.

Suggested Demonstrations

1. Since students have a tendency to throw powders and solids into a sink and to wash them down the drain, the following experiment will help to emphasize the need to use a waste receptical. Place 5 grams each of zinc powder and solid ammonium nitrate on an asbestos square (6" x 6"). Add a few

drops of water to the mixed reagents. A dense white cloud of zincoxide is evolved. When few crystals of iodine are added to the mixture and the color of the cloud will be violet. This demonstration also illustrates that water can start a fire as well as put it out. Hence water should not be used to extinguish a chemical fire.

To emphasize that chemicals in the lab should not be mixed indiscriminately the following demonstration is suggested.

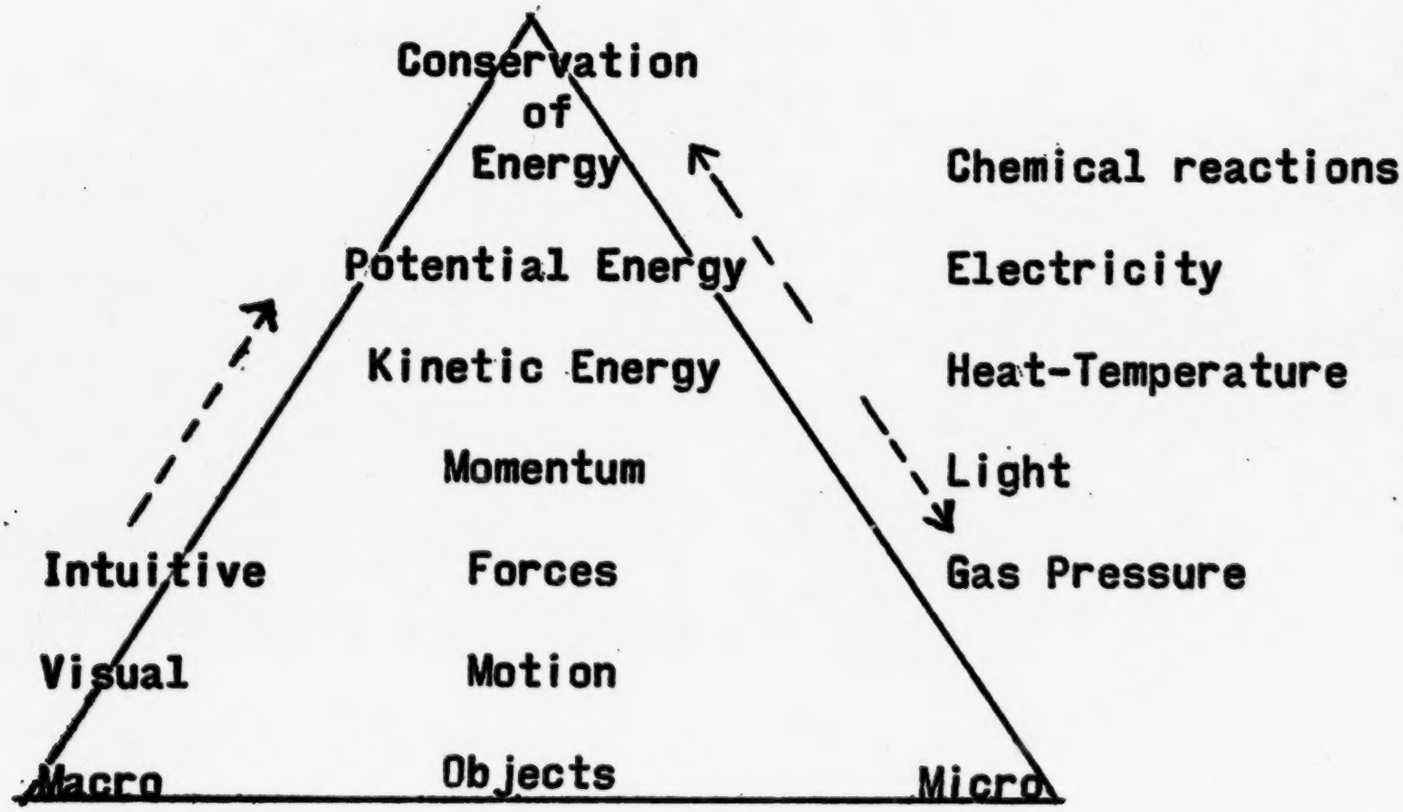
II. Mix carefully equal volumes of granular potassium chlorate and granulated sugar. Add a few drops of concentrated sulfuric acid and stand back. (should be done on 6" x 6" or larger asbestos square.)

The previous two experiments are from Tested Demonstrations in General Chemistry by Hubert N. Alyea, there are a great many other chemical experiments that could be used to emphasize safety in the laboratory and to make the student more observant.

III. In the realm of physics there are several demonstrations that may be helpful in emphasizing techniques of observations in science. To show how time intervals can change perceptions an ordinary large fan can be used in conjuction with a strobe light. By marking one of the fan blades and by altering the frequency of the strobe's flashes, theffan's blade can be made to appear to go forward, backward, or appear in several distinct or multiple positions simultaneously.

Conceptual Framework

FIGURE III



The left hand side of this model of the Conceptual Framework of Chemistry-Physics represents the use of student perceptions of the macro world and intuitive knowledge primarily applied in an inductive process to develop concepts . The right hand side of the model indicates that a topic can be inserted into the framework at some point and then, by the application of either deductive or inductive processes, relate it to the total conceptual pattern. In this manner the student is lead to a higher degree of abstraction at all levels, including the conceptual model of the micro world of atoms and particles.

TEACHERS INTRODUCTION TO UNIT ONE

COMMUNICATION

The content of this unit is a vehicle to illustrate the methods of science and to establish a common semantic background from which to expand and elaborate into specific scientific material. The object of the first portion of the course is to make the student aware of the inductive approach to science. Later in the course the deductive approach to science will be illustrated. A combination of inductive and deductive processes will be used as the intellectual maturity of the student increases.

The purpose of unit one aims to focus attention on the inductive process and to lay a foundation for a common level of communication between student and teacher.

The inductive process can be illustrated by the following steps whichare in reality the sequential learning process that a child undergoes in his development of communication:

A. Perceptions - use of senses

B. Representations of <u>real</u> things

C. Symbols - words, letters, etc. that stand for objects and/or perceptions

D. Sorting factors - analysis of data-grouping-formation of ideas and relationships

E. Abstractions - specific to general.

The deductive process in science reverses the order of the above steps. Starting from an abstraction or generalization the implications are logically defined, then tested. Traditional laboratory experiments were written in a deductive manner.

Since a major difficulty of students not primarily interested in science is fear of scientific and mathematical symbolism, this unit begins by examining some of the processes of analysis using materials andexamples from the non-scientific world. The literature on language and thought (References 8, 16, 17, 38, 40) will be helpful to the teacher for developing a background of understanding for this lesson.

The objective of this total unit is to produce a change in the student which reflects an operational understanding greater than the sum of the skills developed in each sub-section. The student should develop an awareness of a conceptual framework in which the "Gestalt" of the framework includes the individual items and the <u>relations</u> of the items to each other.

It is the unique feature of this course that the student grows to an awareness of this latter idea and its importance to science. In the development of the unit the items should be of a simple, familiar nature in order that the relationships be developed. Later in the course both the individual items and their relationship will need to be developed. Both are an integral part of the course.

Initially the student begins with objects (or perceptions of objects) and proceeds to representations of objects, symbols for objects, and finally awareness of low and high order abstractions. The ambiguities and double meanings of words should be kept to a minimum, but the student should be made aware that ambiguities do exist.

Though it does not follow the logical order of the development of communication in an individual, as previously listed, an awareness of the meaning of perception may be developed for the students through an exercise on the meaning of representation. To show that a representation is not the object, one could divide the class into groups "A" and "B". Group "A" should be asked to close their eyes and Group "B" would be shown a 400 ml. beaker from a collection of different beakers. "B" is then asked to convey the idea of the beaker to the"A's" without using words or numerals. The idea of a beaker may be conveyed by a sketch on paper or chalkboard. The size of the beaker may not be conveyed. From "B's" sketch Group "A" is asked to identify the beaker from the selection.

The variety of identifications will illustrate that communications between the two groups is only partially successful. This same type of thing can be done with bottles that are the same in size, shape, but not in color.

The limitations of representations-akin to the limitations and complexities of some early forms of sign languages-are thus demonstrated. Ways of producing a representation which can be associated with but one object as opposed to a group of objects should lead to a discussion of the acuity of perceptions required to identify one item from a group.

In guiding the students from representations into perceptions, the emphasis is on the act of using the senses to perceive and observe objects and phenomena.

The student should become aware that a perception is a neurological process and as such is an individualistic phenomenon. The perception of the object may occur simultaneously by many persons but the actual perception of the object is unique to the individual. This may seem to be a fine point but it is the beginning of an awareness of the problems involved in effective communications.

A follow up of the previous discussion on the limitations of representations could be a directed discussion on the use of symbols. Symbols are abstractions of objects, representations and perceptions. If difficulty is encountered with the transition from representation to use of symbols introduce the problem of representing verbs (In this situation mathematics and science could be injected into the discussion.) The simplicity and definitive nature of +, -, x, ÷, = etc. should be developed. "Force" can

be discussed as an idea which can be symbolized by a simple sign, like "$\longrightarrow$", called a vector. The usefulness of such a symbol will depend upon the universal acceptance of its meaning.

In the homework sheets for this unit there are no correct answers, since the instructions to the student asks for a judgment on their part.

The mental process of grouping is so frequently used by students that their awareness of the process is like the awareness of gravity. A typical wish or an opinion statement by a student could be analysed to show the use of grouping and the sorting factors used in designating the group. The student should be aware that the usefulness of the grouping process is dependent on the selection of a characteristic or relationship (sorting factor) which is pertinent to the study or problem. The teacher should be aware that organization of multitudinous knowledge into categories allows man to a) study natural behavior, b) observe consistencies in behavior and c) predict behavior.

The purpose of the study of "abstractions" in this unit is to help the student grow a) in his awareness that the level of abstraction of a concept can be determined by the numbers of sub-groups in the concept and b) in his ability to use an upper level of concept without associating it with specific sub-groups.

"Ambiguity" is introduced with respect to clarity of communication and choice of words. It should develop from this base into its quantitative aspect involving precision vs. accuracy in measurement. The teacher should bind the two aspects of ambiguity into a continuum.

UNIT I

STUDENT READING I, PERCEPTION

Some fourteen to eighteen years ago you were born into a world of harsh environmental conditions. You left an environment that was always the same temperature and was protective. You were born! You faced a new environment and were experiencing sensations about which you knew nothing. Your mind was a blank.

In the time that followed your birth your perceptions were limited. You could distinguish between light and dark, warm and cold; you could feel hunger and pain but could not formulate many thoughts. As a baby it took four to six weeks for you to be able to perceive gross characteristics and thus to distinguish some objects and to tell the difference between your mother and father. Your brain and eyes had to develop so that they would work and function together. Finally you could feel textures with your hands and tongues, you could experience taste, you became aware of sounds and formed an image of your environment. (You could associate that which was pleasant from that which was unpleasant.) You cried when you were hungry, you gurgled and cooed when the hunger was alleviated and were again comfortable.

As you matured you learned to associate words with objects, (that a word represented an object) to formulate the words by listening to your parents, to put words together in simple phrases and unconsciously to realize the association of thoughts and actions with words. The formation of thought pattern progressed at an astounding rate.

This situation illustrates that a person is conditioned to perceive one detail and exclude the unpleasantness of the background.

As one walks into a room and looks around he usually observes the entire room, the people in the room are noticed and only those who are unusual are observed. An example of this would be what the Secret Service Agent protecting the President of the United States looks for as he surveys the crowd of people who have assembled to hear the President speak. The S. S. Agent does not see each individual in the crowd, he is looking for the person who is acting a little differently from the rest of the crowd.

Conditioning since childhood causes one to see the whole of a situation at the expense of detail. Men and boys are more likely to see the whole of a situation than are women or girls. To illustrate, if a boy looks at a girl he sees all of her and forms an opinion of pleasantness or unpleasantness. A girl on the other hand is more likely to notice such details as the way the hair is combed, the cut and fit of the clothes, the color of the lipstick. Then, if at a later time, the boy is asked to describe the girl he would say she was pretty, or a good "looker" and would describe her in generalities. The girl will describe the other girl by going into detail concerning the color of the clothes, the matching ensemble, the color of the lipstick, whether the nail polish matches the lipstick, and other items.

If asked, one can see details and differences. Ask a person to find differences in two cars fresh from the assembly line, same in color, accessories, and engine size. In a short period of time a list can be compiled of the differences. A screw may be in crooked in one and not the other.

car, a small scratch may be noticed, or any of many other differences. Perceptions can be developed by making a conscious effort to do so. The ability of people to observe and perceive must be developed in order to get a clear picture of the world in which we live.

Perceptions are a result of the stimulation of the senses. A child, learns through the use of the senses. A mother holds a rattle, a ball, or a doll and repeats the object's name. The child then associates the visual perception of the object with the name of the object. The child knows that the word "ball" is a ball because his mother told him so. When a child reaches toward the hot stove and the mother yells "No!, No! Hot!" the words mean very little. However, if the child touches the hot stove and feels the heat then the word "hot" has meaning for him. Likewise a child learns what taste, sound, and odors are from direct experiences. These experiences illustrate how we learn to verbalize our perceptions.

Symbols

In discussing perceptions, a great many words could be expounded and studied, but words are only symbols. Symbols are ways of representing perceptions in a conscise manner. A picture is a representation; when representations are verbalized, the verbalized form becomes a symbol.

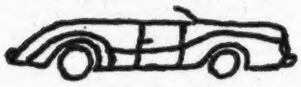
In studying science or history or English, the symbols that are used take many different forms. As an example the liquid in which we swim and which we drink is called water. In science the symbol for the word water is H_2O; the word "water" is also a symbol. In the study of history the symbol can mean at least two different things. To the

American Indian, 卐 is the sign of the "thunderbird", to the German people the 卐 is a swastika and refers to the Nazi party, or the S. S. troops of the Hitler era.

A representation is a picture while a word or abbreviation is a symbol. There are many instances where a representation and a symbol are the same. To further illustrate ♀ is a biological symbol for female, but to the alchemist it was the symbol for copper which is now symbolized as Cu; ♂ is the biological symbol for male, but to the alchemist it was the symbol for iron, which is now Fe. If a person perceives the odor of civetone (skunk) and you observe him holding his nose, you are aware that he has observed something unpleasant. In past experience the act of holding your nose represented something unpleasant whether the unpleasantness was an obnoxious odor or something else. Symbols, then, are shorthand ways of conveying thoughts, representations and/or perceptions.

REPRESENTATIONS-PERCEPTIONS-SYMBOLS

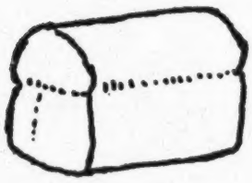
Directions: The following sketches are representations. Write symbols which will indicate your perception of the representations.

1. 

1.

2.

2.

3. 

3.

4.

4.

5.

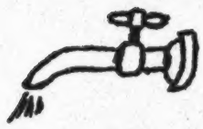
5.

6.

6.

7.

7.

8. 

8.

9.

9.

10.

10.

11.

11.

12.

12.

13.

13.

14.

14.

15.

15.

REPRESENTATIONS-PERCEPTIONS-SYMBOLS

Directions: Make representations of the following symbols on a separate sheet of paper.

1. clock
2. BHS
3. test tube
4. beaker
5. book
6. meter
7. amoeba
8. pen
9. pipe
10. lighter
11. five
12. pool

UNIT I

STUDENT READING 2

SORTING FACTORS

Suppose that as you came into the school in September, each member of the school population were asked to fill out a card questionnaire. On the card you were to write your name; last name first, first name last, your age; your class; your curriculum; etc. Then these cards were all placed in a box and you were asked to organize them. How would you organize them? What would be the criteria that you would use so that the organization would be <u>useful</u>?

As you consider the above exercise, several <u>sorting factors</u> should come to mind. Initially, you may sort according to grade level (10th, 11th, 12th). Then you might arrange them in alphabetical order according to age, or in alphabetical order according to the curriculum. There are many different ways of arranging these cards that would be useful and informative both to you and to the principal.

Suppose school begins and you walk into a science classroom that contains a great many boxes of equipment and supplies and the teacher asks you to help organize and distribute the equipment and supplies. Where would you begin and what would be done? Your first reaction may be, "Why should I?" Of course you may also consider various ways to separate the supplies. First most of the glassware such as beakers, graduated cylinders, and test tubes should go to the chemistry area while petri dishes, microscope slides, cover slips, clay pots should probably go to the biological areas. Where would indicators (litmus, brom-thymol

blue, etc.) be directed? An entirely different set of factors must now be considered. In all probability both chemistry and biology would need indicators so they should be placed in an area where both the chemistry and biology teachers could have access to them. These examples enumerated here are processes that you utilize everyday of your lives. Sorting factors and groupings take place in your minds continuously. The recognition of the relationships of objects and the common uses to which the objects are placed illustrate processes used both in and out of school. The grouping and sorting of objects by their common characteristics, relationships, and uses is important. This is done by small children and continues to be done in ever more complex situations as children mature and take their places in society as adults.

To further illustrate the process of sorting, consider the following situation: In the spring of the year when school is beginning to get you down and "spring fever" has a good grip on you, your parents ask you where you would prefer to go on a vacation. If you select the shore you have automatically excluded the far-west, the mid-west and the mountains of Pennsylvania, New York, Vermont, etc. You have, in the statement, "the shore," used the idea of sorting factors in reverse. In stating "the shore," most of the country has been eliminated from the discussion.

A teacher of English has a major sorting job to do. A choice must be made as to what books should be studied in literature; what and how much grammer and writing should be stressed. In a history course a great many topics could be covered but as indicated by the title, certain sorting factors are employed such as the relationships of events and the usefulness of the subject matter to illustrate a phase of history to select the content of the course.

Common characteristics, relationships, and usefulness are, therefore, the factors that must be considered when objects, data, and varying situations are to be cataloged. In examining a Sears catalog or similar publication, you wouldn't look in the section on womens clothing to find a fishing pole or surf board. The grouping and sorting has been done for you when the catalog was printed.

UNIT I

SORTING FACTORS-GROUPING

Directions: Examine the following list of symbols carefully.

I. Select as many sorting factors as are needed in order that every item is in a group. (Are the sorting factors usefull)?

II. List the sorting factors.

III. Arrange the following symbols according to the sorting factors selected.

NOTE: Symbols may be in more than one group.

1. scalpel
2. dropping pipette
3. volt meter
4. balance
5. test tube
6. spring
7. microscope
8. radioactive chemicals
9. projector
10. salt
11. probe
12. sponge
13. microscope slide
14. magnet
15. matches
16. light bulbs
17. alcohol
18. books
19. clock
20. rocket
21. ammeter
22. cigar
23. ring stand
24. tomato
25. frogs
26. map
27. cover slips
28. paper
29. test tube holder
30. camera
31. beakers
32. onions
33. tape recorder
34. magnet
35. wire
36. ramp
37. flasks
38. pants

39. Bunsen burner
40. wolf
41. carbon dioxide
42. amoeba
43. airplane
44. zinc
45. compass
46. pencil
47. refrigerator
48. telephone
49. ice
50. paper clip
51. sulfur
52. tape
53. diamonds
54. radio
55. spring
56. letter
57. rubber bands
58. paint
59. autoclave
60. sugar
61. still
62. acids
63. forceps
64. typewriter
65. magnifier
66. coffee
67. wing tip
68. meter stick
69. graduate
70. note pad
71. film
72. brush
73. shirt
74. cards
75. record player
76. stop watch
77. marker
78. calcium

UNIT I

STUDENT READING 3

ABSTRACTIONS

In the study of biology and classification of animals, protist and plants was studied. A wolf is a specific member of the specie, lupus; the genus, canis (as are dogs, foxes, coyotes); the family canidae (includes all dog-like animals); the order, carnivora (meat eaters); the class, mammalia (warm blooded animals that nurse their young); the phylym, chordata (animals with backbone or internal skeleton); the kingdom, animal. With this example, two things should be noticed; first the grouping or sorting factors involved, and secondly the level of abstraction. Notice that as you examine the classification of animals that you usually start with a single word that refers to a specific animal. Wolf, then, is a low level of abstraction, while animal is a high level of abstraction, and encompasses a great many organisms.

A student is a member of an individual class, the individual class is a member of the junior or senior class, the junior class is a member of the school, which is a member of the community etc. This type of abstraction and the levels of abstraction have been expressed in the set theory of mathematics in the definitions of element, set, union, and intersection. An element is a single object, person, etc.; while a set is a grouping of well defined elements, a union is a set of sets; and an intersection is a set of elements that are common to two or more sets.

In studying the History of the U. S. one studies the history of a particular geographical area through an era of time. Then another area is studied and the similarities and differences of growth in these two areas

are compared. In world history a similar process takes place and you go from country to country and from era to era. The complexities of history, English, science and mathematics always seem to evolve from low level abstractions to high level abstractions and generalities.

Perceptions are the basis of ideas, concepts, and understandings. Communication usually takes place in words. It is true that certain thoughts and ideas can be conveyed without the use of words but situations of this type are rare and ineffective. In the learning of a new language you need a starting point. As a starting point a language teacher begins with words in the new tongue and associates them with objects or compares these with words of parallel meanings to the native language. So it is in science, mathematics and other subjects; one must learn the language before effective communication can take place.

Ambiguities

The words plane and plain are pronounced the same way, but have radically different spelling and meanings. To further illustrate: bare (naked) and bear (animal); pair (two) and pear (fruit); red (color), and read (book, present and past tense); loaf (bread) and loaf (to waste time); stair (steps) and stare (gaze fixedly), are words that are frequently misinterpreted because they have the same pronounciation and/or spelling. The word ambiguity seems to fit the dilemma of words that sound the same but have different meaning.

Ambiguities can refer to situations as well as words. Two cars collide at an intersection and the collision is viewed by two or more people. Accounts of incidences in the newspapers reporting of what people think they see are many times conflicting. Being able to express yourself in a clear, concise manner will decrease the ambiguities of communication.

Precision vs. Accuracy

In space an error in measurement of a small part of a degree can cause a rocket to completely miss an object the size of the moon. To illustrate, it has been said that to fire a rocket to the moon is analagous to hitting a fly in the eye with a .22 caliber rifle from a distance of one mile. In order to hit a specific spot on the moon involves even more considerations. These examples illustrates precision. In the days of the gold rush to California the weight of a freight wagon of supplies could be measured on large scales and an error several pounds didn't make much difference. A bag of gold, on the other hand, was measured to a very small part of an ounce. Gold was worth sixteen to thirty dollars an ounce. The same scales certainly could not be used to weigh both freight and gold.

A laboratory balance can measure with an accuracy of 1/100th of a gram while certain analytical research balances have an accuracy of 1/10,000th of a gram or more.

The precision involved in the laboratory balance and the precision of the research balance are very different, but one can measure with as great an accuracy (within the limits of the instrument) as one wishes.

Precision is a property of the instruments that are used while accuracy is your ability to use all of the precision that is built into the instrument. The accuracy involved is your ability to obtain very similar measurements, within the limits of good measuring techniques, for the same dimension using the same instrument.

Answer the following questions in a clear concise manner.

1. What are your understandings of the following:

   a. representation

   b. perception

   c. symbol

   d. referent

   e. sorting factor

   f. relationship

   g. abstraction

   h. ambiguity

2. Have you and the class a common meaning for the terms in the previous list? If not what should be <u>your</u> next course of action?

ABSTRACTIONS

Directions: I. From the following list of symbols sort into catagories, then group according to level of abstractions, i.e. from low to high abstractions. (Items may be used more than once.)

II. Refer to HW I-3 and make a list of symbols that have more than one meaning tc you. Enumerate the meanings.

American

animal

atom

book

Buick

Buick Riveria

car

CP-I text

Delawarean

earth

electron

employee

father

General Motors

homo sapiens

man

metal

Mr. Adams

molecule

paper

printed material

Republican

salesman

solar system

text book

universe

TEACHERS INTRODUCTION TO UNIT II

INVARIANT RELATIONS

Prediction of natural behavior is dependent upon the existence of invariant relations between elements of a system. Much of our daily activity is directly controlled by invariant relations. It is expected that all cars go on green and stop on red, that goodness will be rewarded, that stress will cause bending of some material and breaking of others. One plus one is two. The laws of science are statements of invariant relations of natural behavior.

The process of science involves the seeking of invariant relationships. This unit proposes to seek situations in which the perceptions of two parameters (qualities) of a single situation can be identified and compared. The situations are selected without regard to subject but should be familiar to the students and have use later in the course.

The sequence of the content is designed to lead the student from the static qualities of weight and volume to the active qualities of elasticity and to the obscure qualities of electrical conduction.

Two concepts are side lights. First, ambiguity is to be expected and tolerated to the degree that more refined perceptions can not be obtained in the given circumstance. This is illustrated in determining the measurements for calculating volume.

Secondly, predicting behavior from limited evidence, extrapolating, has potential dangers. Hence verification of predictions by experimentation should be made whenever possible. This is illustrated in the problems on Ohms and Hooke's Law.

Lines and Figures

The initial work with lines and figures is not intended to teach geometry as such but to give the student a new point of view of some old ideas. Exact geometric language is not necessary although care must be taken not to be in conflict with the language of the contemporary mathematics. When constructing the geometric figures for the purpose of seeing the rigidity of a triangle, strips of peg board could be used as they would afford multiple places of fastening by means of cotter pins or brass paper fasteners.

Density

In the section on density the intent is to find an invariant relation between weight and volume for any one material. After the class has discovered this relation, then and only then, should the relation be given the name "density" for reason of easy communication. It should be stressed that the relation of w/v is important to the understanding of natural behavior and that the word "density" makes communication easier if and only if all parties understand the behavior.

In the same manner the mathematical term "ratio" should be introduced after the work is done simply as a name for a process.

The student instructions are designed to give the minimal directions without making the inferences for the student. The teacher will have to supplement the instructions to the degree necessitated by the level and background of students.

The development of the concept of specific gravity follows as an invariant relation of invariant relations.

Hooke's Law

The work with Hooke's Law introduces the graphic representation of qualities. A minimum of technical language should be used in developing the concept. Independent and dependent variables are associated with "controlled" and "reactive" behavior. The term "function" could be introduced to mean the relationship of two variables.

Note that the invariant relation which is found in this unit is the reciprocal of the spring constant as usually found in textbooks. The constant developed in the lesson fits the pattern of what is actually performed by the student. References should be used with care.

The work with rubber bands and certain plastics extends concept to those materials in which it applies to a limited extent. "Hookian region" should be made meaningful.

Ohms Law

The student instructions are detailed to emphasize the need for safety when dealing with electricity. Meters are not explained as they are used only as devices to extendman's perception to the obscure. Volts and amperes are used as two qualities of electricity without further explanation. After the relationship is found it may be labeled "resistance". Care must be taken not to call the conductor a resistor until after the idea of resistance is found.

Solubility

Since this is the first work of a chemical nature to be done in the laboratory, it is important to teach the fundamentals of laboratory safety.

In addition to the collecting and plotting of data on an individual basis each student should plot the data of the entire class. The importance of a large quantity of data as a means of establishing an inference in spite of ambiguity is illustrated by this procedure.

No laboratory sheets for the student are included in this guide. Experiments such as "Experiment 11 - To Determine the Solubility of Common Salt" and Experiment 12 - The Solubility of Potassium Nitrate at Various Temperatures", in Laboratory Experiment for Physics and Chemistry by Hogg and Bickel; D. Van Nostrand Company, Inc., 1961 can be utilized.

Problem Solving

The student is given a lead to the solution of pborlems by applying two processes: (1) identifying qualities and/or characteristics of objects or situations and (2) sorting according to the invariant relation involved in each problem.

If possible, have the problems relate to items which are in the laboratory. Upon completion of the problem have the students verify the results in the lab. This may serve as a test situation in which the processes, content, and laboratory techniques can be evaluated.

Resorting

The items selected for the content of this unit cross the usual topics of science. The items should be resorted into the usual topic headings as an exercise in grouping and to facilitate the use of the content as references in future work.

UNIT II - RELATIONS OF LINES

Laboratory I

1. With a straight edge draw 10 examples of two interesting lines. Label the angles formed by each pair of interesting lines in a clockwise manner with the numbers 1, 2, 3, 4. .....

2. Measure the angles with a protractor. Write the results of the measurements in the following table.

Case	1	2	3	4
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

3. From the 40 individual items, do you perceive any relations which would:

(a) reduce the number of actual measurements which would have to be made in repeating the exercise

(b) make it possible to predict the value of one or more angles from the known value of one angel.

UNIT II

RELATIONS OF MEASUREMENTS

HOMEWORK I

Measure the circumference and diameter of 5 circular objects. (Hint: the base of a cylindrical object will suffice. Records, cylindrical glasses or vases, large coins, buckets, paint cans, food cans, etc. will do. Wrapping non-stretchable string or thread about the object is one method of determining circumference).

Complete the table.

Case	Circumference	Diameter	$\frac{\text{Circumference}}{\text{Diameter}}$
1.			
2.			
3.			
4.			
5.			

What inference could be made from the above data?

What symbol is associated with this inference?

In what kind of situations is this information useful?

UNIT II - RELATIONS OF QUALITIES

LABORATORY 2

1. Determine the weight and volume of an object. Repeat each individual measurement (such as weight, length, width, etc.) three times.* Record your linear measurements, weights and volume in a table.

2. Compare the weight to the volume (w/v) and put this in the table.

3. Record in table form the results of the entire class.

4. Does this information lead to any inferences concerning the material which was used?

5. Could the inferences be extended to other materials including liquids?

6. Determine w/v for pure water and another liquid.

*Refer to Lab Supplement on Metrology

UNIT II - METROLOGY - A

LABORATORY SUPPLEMENT

How would you measure the distance between two lines, A and B? Most people would place the zero mark of a rule on line A and read off the distance at line B. In doing so you would be guilty of poor technique. This is not the way to get the most accurate results. The explanation of why this is so takes us into an involved but understandable world of the problems of measurement. Today's requirements in science and industry have suddenly raised the need for better measurement.

When you measure you perform two quite different operations. In the first place you use some sort of standard, and you compare the standard with the distance to be measured. You actually count the number of units within the distance you are measuring. If you do this you will find that the distance does not come out an exact number of units on your ruler. You must estimate this excess distance. This process is called interpolation.

The trained metrologist (a person skilled in the art of measurement) would proceed to measure lines A and B in the following manner. He would place the ruler at random, making no attempt to line up on any mark. He would then take readings where A and B intersect his scale. He would interpolate both readings. After a sufficient number of such readings he would determine the average of the readings.

In the case where we set the zero index on line A we immediately have an error. Setting the zero on a line involves judgment. The operator, if he makes a series of such settings, will probably have a systematic setting error - he will tend to misjudge always by the same

amount, He will always set a little off in the same direction each time. The operator again has trouble when he reads the value for the B intersection. He will get the same counting number each time. He will remember previous interpolations and tend to repeat the figures.

Hence, when he makes a series of ten measurements they may come out very nearly alike. Their average may vary only slightly from the extremes he recorded. It will look like very good measurement. It may be quite poor.

Systematic errors of setting, of remembering, of local ruler error cannot be eliminated by merely taking more measurements. The results will be most misleading.

The method of the metrologist is a way of avoiding systematic errors. The ruler is placed at random. This eliminates the setting error. It also means the reading at B has no similarity numerically to the previous reading at B. There is nothing to remember, nothing to sway his judgment.

To be sure, there will still be errors of interpolation, but they will be more random than with the first method. Random errors can be compensated for by increasing the number of readings. Because different parts of the ruler are used, errors in the ruler tend to be averaged out.

This new method does not eliminate all errors. If the ruler has shrunk, a systematic error will appear.

The results of the new technique will often give scatter to the results of repeated readings that make the older method look much better. But if agreement of measurement depends on systematic errors, no amount of agreement means anything.

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UNIT II - METROLOGY - B
LABORATORY SUPPLEMENT

Progress in man's effort to understand the behavioral patterns of nature is dependent on his ability to make keen and detailed perceptions and the recording of the perceptions in a clear, understandable manner. This is the basis of intellectual integrity.

Are you satisfied with the measurements you made? Did you make each one independently or did you allow a previous measurement to influence your actual perception and/or recording of the measurement?

In spite of (or because of) your best efforts several measurements of the same dimension may have different values. Estimation is a part of each measurement as you must locate a starting point and an end point. The process of measuring length can be refined by using instruments which reduce the length of the possible places where the boundaries of the dimension might be located. Note that estimation is not eliminated, it is refined.

Calipers are instruments which refine the measurement of length. Two varieties are avilable; micrometer calipers and vernier calipers.

Repeat step one of the lab problem using calipers. Judge whether these measurements reduce or eliminate the scatter of your results.

UNIT II - RELATIONS OF VARIABLES

LABORATORY 3

Materials have behavioral characteristics (qualities) that often can be measured. Words like "action" or "reacting to (something)" are often used in these situations. Examples might be the reaction of a tree to the change of seasons; the reaction of wood to a flame; the reaction of glass to a thrown ball; or the reaction of a spring to the weight of an object attached to the spring.

Your problem is to examine by experimentation the relation between the weight of the object and the reaction of the spring. Examine the process that was used in the previous lab problem including generalized inferences and verifications. These processes will serve as a guide to the procedure to be used in this problem and the methods of recording the data.

This problem differs from the previous one in that one of the two items, weight, can be varied by the scientist. Therefore treatment of the data will be somewhat different. The item which the scientist controls-in this case the objects which are attached to the spring--is called the independent variable. The other item, the reaction of the spring, is called the dependent variable. For each spring use several independent variables and measure the dependent variable. These data should be recorded in a table.

A pictorial representation of the data is a good way of perceiving the relation between the two variables. This type of representation is called a graph. By universal custom the value of the independent variable

(weight of the object in this problem) is plotted along the x-axis and the value of the dependent variable (amount of spring reaction) is plotted along the y-axis. The word "curve" is associated with a line which connects the points on the graph regardless of the path the line takes.

Inferences concerning the relation of dependent variable to the independent variable should be made from the data and the curve on the graph.

Can you imagine a situation concerning a spring in which the variables would change places?

Are the inferences concerning the reaction of the spring applicable to other materials? Select a few representative materials such as rubber bands and strips of plastic and verify your predictions. (Hint: Do verifications have limitations?)

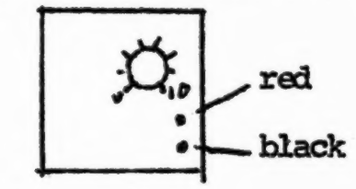
UNIT II RELATIONS OF OBSCURE PATTERNS

Some natural behavior is not obvious to the senses hence human perception may be non existent. In many cases it is impossible for a person to perceive that a current of electricity is passing through a wire. There may be some indirect evidence such as heat or light that electricity is present. Because of his inability to perceive electric currents man has learned to be wary of them and to find means of perceiving them indirectly through electrical meters.

Man has found that by means of meters he can measure two qualities of electric current. These are voltage and amperage. Is there an invariant relation between these two qualities? To determine this you will need to use (1) a source of electricity, (2) an ammeter, and (3) a voltmeter. You will also have to use a particular conductor of electricity.

Since you are depending on the indirect perception of electricity through meters and since you must be wary of electricity it is important that you use the meters in the only acceptable way to get reliable information. Follow the directions and diagrams below very carefully.

These are the symbols and their meanings which shall be used.

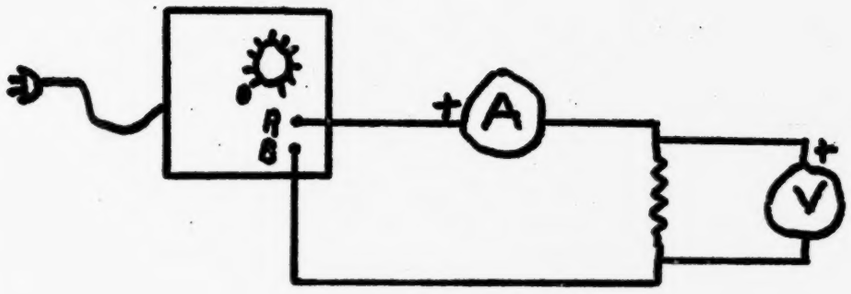


—electrical source

—ammeter

—volt meter

—the specimen conductor under consideration



1. Do not plug in the electrical source to the wall socket until you have completed the wiring and the teacher has inspected it.

2. Connect the red outlet of the electrical source to the + terminal of the ammeter.

3. Connect the _ ampere terminal to one end of your conductor specimen.

4. Connect the other end of the conductor specimen to the black terminal of the electrical source.

NOTE: At this point you now have a complete circuit which will permit a flow of current and measure the electrical current through the conductor.

5. In addition to the connections already made, connect the end of the specimen conductor adjacent to the ammeter to the + terminal of the volt meter.

6. Connect the other end of the specimen conductor to the _ terminal of the volt meter.

7. At this point ask the teacher to inspect your wiring.

8. After you have had your wiring approved, set the control knob of the electrical source at "0" and plug in the source to the wall socket.

9. Adjust the control knob to get a perceptable reading on the

ammeter (the independent variable) and read the resulting voltage across the specimen on the volt meter (the dependent variable).

NOTE: At no time should the meters be made to go beyond their limit (off scale).

10. As in past lab problems record the data, make a graph, and make inferences that seem justifiable from the data and graph.

11. Check your inferences by using several more specimen conductors.

NOTE: A battery and rheostat in series may be substituted for the power supply. In the above directions the red outlet of the power supply would represent the position (+) terminal of the battery or rheostat and the blue outlet the negative (-) terminal of the battery. In item (8) the condition desired would be attained by setting the rheostat at maximum resistance at the beginning of the experiment.

UNIT II - INVARIANT RELATIONS
STUDENT READING

It is commonly said that the only thing a person can depend on is that change will take place. As true as this is, the world would be an impossible place to live in if we couldn't depend on some things. How many fundamental things do you depend on? Do you feel safe when crossing a highway when the traffic light is green for you? Every day thousands of people take off from American airports expecting to land at a specific European airport. How many items of natural behavior are these people depending on?

An invariant relation is a way of expressing those qualities and reactions of natural things on which one can depend. We expect rubber bands to stretch. We depend on the strength of steel when we build bridges. We know that certain vegetation will not live at high altitudes. We anticipate the characteristics of successive generations of living things. Do you "know" what to expect when you put sugar, salt, or vinegar on the food you eat?

Acquiring a knowledge of invariant relations has made possible an organized body of information called mathematics. By seeking and classifying the invariant relations of natural things and their reactions man has been able to reduce the almost infinite number of individual bits of perceptions to a relatively few laws and theories. In this unit you have sought a few of these invariances in the manner of a mathematician, a physicist, and a chemist.

With the limited knowledge you now have, you can predict many things. From a table of densities you can predict the volume of a known weight of a substance. Knowing the resistance of a conductor you can predict the electrical current produced by a voltage. Knowing an invariant

relation may be fun but the ability of man to use them to predict and then to control events is the ultimate in understanding, using, and controlling his culture.

TEACHER INTRODUCTION TO UNIT III

MOTION

The purpose of this unit is to use the previously introduced technique of grouping and seeking invariant relations to develop the concepts of straight line kinematics and to apply these concepts to more complex motions.

Many types of motion are set up in classroom. These should include those examples mentioned in Laboratory III-I and as many others as time and facilities permit. The student is asked to group the motions into catagories with special attention to the selection of sorting factors which would serve some useful purpose. If necessary the discussion should be directed to straight line motion as a sorting factor as this is the motion where the relation between displacement and time is to be sought.

An extension of this initial discussion of the perceptions of motions to the ambiguities caused by different points of view should lead to relative motion and the concept of frames of reference.

By means of an overhead projector or chalkboard a grid may be used to show students how to describe the position of an object in space through the use of a frame of reference and ordered pairs (coordinates). Some students may be able to extend this concept to a three dimensional model. In order to simplify the problem for the study of kinematics, displacement should be related to the number line and the use of positive and negative numbers to indicate location. When determining the change of position or displacement($\triangle S$) the student should use the conventional algrabic notation of positive and negative displacements. The use of the numbered line will avoid the use of vector addition in the early stages of the study.

The concept of displacement per unit time (velocity) is an example of determining the relation between variables. A graphic display of this relationship for successive displacements will generate a variety of curves which illustrate constant velocity and acceleration. Since velocity-uniform or changing-will be used as a sorting factor in the unit on force it is important that this study of velocity be wide in scope. The students should preserve their graphs for future use.

The student should be left with as many leading questions concerning the causes of acceleration as possible to lead him into a study of force in the next unit.

The laboratory exercise on motion (Lab. III-I) is purposely devoid of specific instructions as to how to acquire and record the data and the details of constructing graphs. The students should examine the processes used in previous laboratory exercises and try to apply them to this work. This application of previously developed processes to new situations is a fundamental objective of the course.

The basic data for the experiment can be collected in one lab session. Succeeding class sessions should be used by the students to complete the experiment. Students should be encouraged to proceed as far as possible without the aid of the teacher. Certainly small group or class discussion will be necessary to clarify or solidify a step in the development of the concepts of velocity and acceleration.

UNIT III UNIT III-1

LABORATORY I - MOTION

The purpose of this exercise is to describe and analyze the motions of several objects which have been previously demonstrated to you. These objects are as follows: (1) on horizontal surface: a sliding puck, a rolling ball, and a sliding block. (2) on an inclined plane: a sliding puck, a rolling cart, a rolling ball, and a sliding block. (3) in free fall: a ball. (4) at the end of a restraining string: a sliding puck, a ball swinging in a circle, a ball swinging back and forth.

In describing the motion of a body it becomes necessary to be more specific (or descriptive) than to say "it went that-a-way" or "it went that-a-way moving pretty fast," or even "it went that-a-way moving fast and getting faster all the time." In describing the motion of an automobile we are not only concerned with total displacement, say twenty miles, but with the displacement or distance traveled in a certain amount of time. Therefore, in describing the motion of an object, let us measure its displacement (and other qualities) with respect to time.

In the previous demonstrations we have decided to study the simplist motions first and we concluded that the simplist motion is that which is in a straight line. Following the processes we used in class, the following sequence should serve as a guide. 1. Study objects moving in a straight line. Plot s vs. t. Let t be the independent variable in all graphs since its value is independent in the experiment. What is the relationship between the variables? Do all objects have the same relationship?

Plot ($\Delta s/\Delta t$) vs. t and relate this graph to the s vs. t graph.

The ratio of the distance moved to an interval of time is identified by the symbol "v" and is called velocity or speed.

2. Study objects whose velocity is changing.

How would Δv (charge of velocity) be determined?

Plot $(\Delta v / \Delta t)$ vs. t

Is $\Delta v / \Delta t$ constant for all cases?

The ratio of the change of velocity in an interval of time is identified by the symbol "a" and is called acceleration.

3. Study the motions of the rest of the objects using the methods employed in studying straight-line motion.

a. swinging pendulum

b. circular motion.

What is the value and direction of the acceleration? Do any objects accelerate in a different direction than they move?

STUDENT READING - 1

UNIT III

You have now learned how to describe motion. In your study of motion you have learned how to state the position of an object with the use of coordinates (ordered pairs) and how to find the change in position of the object during an interval of time by using the relation $\Delta s = s_2 - s_1$. That is, the change in position or displacement of an object is equal to second position minus the first. This relation forces us to use negative displacements when the object moves from right to left on a number line such as from +2 to -5. The ratio of the displacement to the time required for that displacement ($\Delta s / \Delta t$) is called velocity and symbolized by "v" if and only if you give direction to the ratio. For example, the velocity of a certain frictionless puck might be 20 centimeters/sec. to the right. When no direction is inherent in the ratio, then the ratio is called speed.

When you plotted displacement as a function of time you found the slope of the curve to be the velocity of the object. You also learned the meaning of constant velocity, average velocity, and instaneous velocity. Next you studied the motion of objects whose velocity was changing and found that the ratio of the change of velocity to the time required for that change ($\Delta v / \Delta t$) was called acceleration. You also found that acceleration was in the same direction as the change in velocity. You plotted velocity as a function of time and found that the slope of the curve was equal to the acceleration and that the area under this curve was equal to the total displacement. By looking at the data plotted on a graph you can tell whether the ratio under study has a constant value.

For instance a graph such as

indicates that the velocity of the object in question has a constant velocity whose value is $\Delta s/\Delta t$. A graph such as

indicates that the object in question does not have a constant velocity and is indeed accelerating.

From the above information several mathematical models of motion have been constructed. These models can be used to describe the motion and to determine specific facts about an objects' position, velocity, and acceleration from data concerning any one of these factors.

You learned that in one case acceleration was invariant regardless of what object was measured. That particular acceleration was the acceleration of a free falling body. You found that all of these objects, when falling, accelerate at the rate of 9.8 meters per second per second ($9.8\ m/sec^2$). This value is called the acceleration due to gravity and is symbolized by the letter "g".

Before undertaking the next unit in your study of the behavior of matter, you might consider the following questions:

1. Do all objects fall toward the earth with an acceleration of $9.8\ m/sec^2$? Cannon balls? Baseballs? Hats? Parachutes? Feathers? If not, why not?

2. If a puck is moving along a horizontal plane, we find it has a constant velocity. Will it maintain the same velocity forever? If not, why not?

3. You found that a frictionless puck sliding down an inclined plane has an acceleration directed down the plane. Exactly what makes this puck change its velocity?

4. Can you explain how a spacecraft can remain aloft indefinitely without the expenditure of fuel?

You may be able to answer these questions either with the use of prior knowledge or your intuition. If you cannot come up with a satisfactory answer, then keep the questions in mind while studying the next unit.

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